

Nanjinoporella, a new Permian dasyclad (calcareous alga) from Nanjing, China

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Synopsis

A new Lower Permian dasycladalean alga, *Nanjinoporella pagoda* gen. et sp. nov., is described from China. It may be closely related to another Asiatic species, *Epimastopora malaysiana* Elliott, and shows an important advance on the incipient annulation of this latter species. Some notes on dasycladalean annulation generally are appended.

Introduction

The material described in this paper was sent to Mu Xinan by Mr Min Qing-kui; it was collected by him and his colleagues from the base of the Chihsia Formation of Lower Permian age (Artinskian/Leonardian) at Chihsia Shan hill, the type locality of the Formation, 25 km east of Nanjing.

Although the fossil alga is represented by only one specimen which was embedded in a piece of dark grey limestone, thanks to the skill of Mr Ji Cheng-dao, of the Rock Cutting Laboratory of Nanjing Institute of Geology and Palaeontology, several orientated sections have been prepared which reveal detailed information about the structure of the calcareous skeleton of the plant. Based on these thin sections, a new dasyclad genus *Nanjinoporella* has been recognized.

Conventional studies of calcareous algae are mostly based on random thin sections. The disadvantage of this method is that the reconstruction of the skeletal structures of the plant is always from different individuals, with the risk that individual sections from different species may be wrongly combined. Hence orientated sections from a single individual specimen are ideal. The preparation of such orientated sections is easier from isolated solid specimens which are available through natural weathering or by etching silicified samples in limestone, and for fossils embedded in matrix it is difficult but not impossible. The present study, describing *Nanjinoporella* and discussing the problem of its taxonomy and phylogeny, provides an example of this approach. Some notes are also given on the annulation structure in Dasycladaceae.

Systematic palaeontology

Family **DASYCLADACEAE** Kützing, 1843 orth. mut. Hauk, 1884

Genus **NANJINOPORELLA** nov.

NAME. Referring to Nanjing, the capital of Jiangsu province, China.

DIAGNOSIS. Near-cylindrical club-shaped dasyclad with large central stem and thin calcareous wall perforated by numerous close-set cylindrical pores, with slight constriction

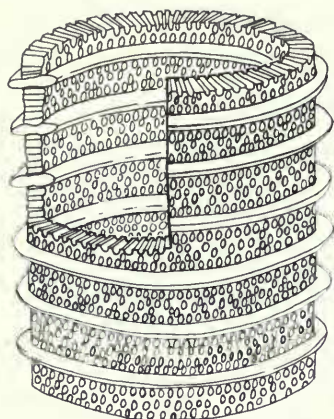


Fig. 1 Reconstruction of *Nanjinoporella pagoda* sp. nov., to show internal and external structure of calcareous wall (size of pores not in proportion).

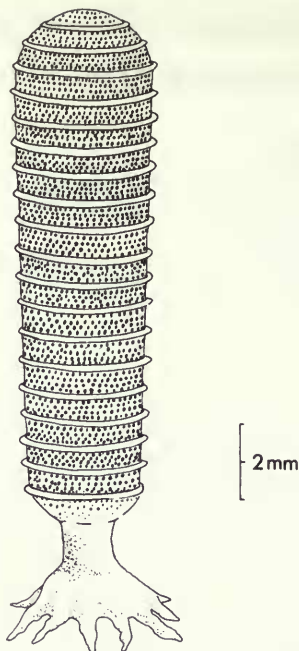


Fig. 2 Reconstruction of *Nanjinoporella pagoda* sp. nov., as in life.

at both ends. Pores show a trend to euspondyl arrangement and are separated at regular intervals by strongly developed outer and inner calcareous annulations (rings), dividing the pores into regular bands or zones.

TYPE SPECIES. *Nanjinoporella pagoda* sp. nov.

***Nanjinoporella pagoda* sp. nov.**

Figs 1–6

NAME. The alga has the appearance of a pagoda.

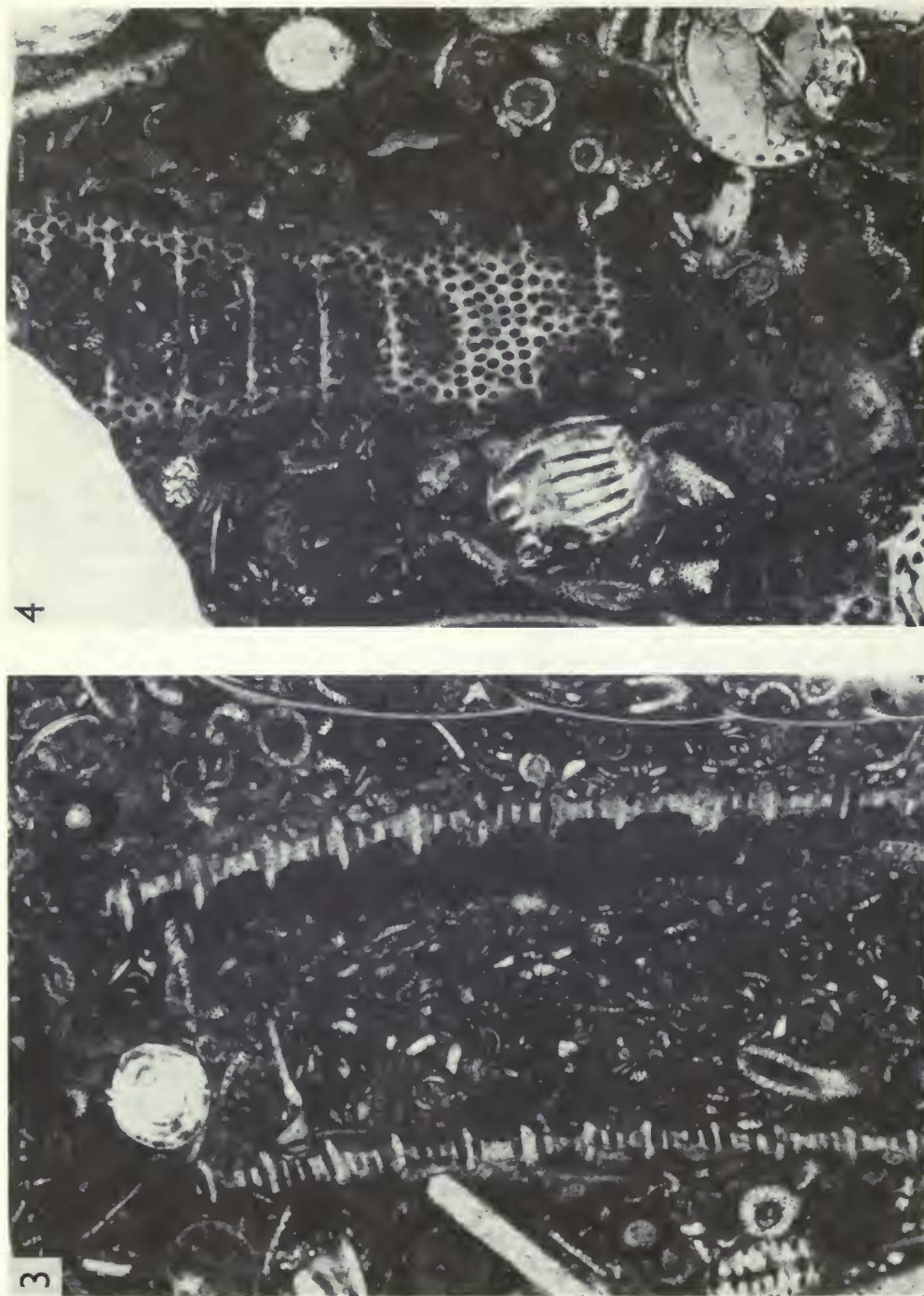
DESCRIPTION. The thallus is largely cylindrical in form and circular in cross section. The observed length (incomplete) is 10 mm and the former total length must have been considerably more. The outer diameter of the thallus increases from 3.63 mm proximally to 4.12 mm distally. Of two cross sections made at the distal part of the thallus, the upper (distal) one is the smaller at 2.67 mm (Fig. 5), the lower (proximal) one being larger at 4.16 mm (Fig. 6). This indicates that the thallus diminishes in diameter near the top and may have been rounded at the end: Fig. 2. The calcareous wall of the thallus is rather thin, 0.20–0.35 mm, compared with that of the large central stem which is 3.20–3.68 mm in diameter. The internal diameter is thus up to 90% of the external diameter (Table 1).

The most remarkable feature of the thallus is the development of distinct outer and inner annulations (rings). Regularly spaced at 0.47–0.82 mm apart, these are 0.44–0.67 mm thick from inside to outside and 0.067–0.16 mm wide vertically, with rounded or tapering edges; they project 0.067–0.20 mm on the inner and outer surface of the calcareous wall. These annulations resulted from extra development of branch-intervals (interpores). They grow horizontally, or slightly inclined upwards. Rounded depressions left by branches exist on the surface of the annulations, which can be seen in the longitudinal-tangential sections, Figs 3–4.

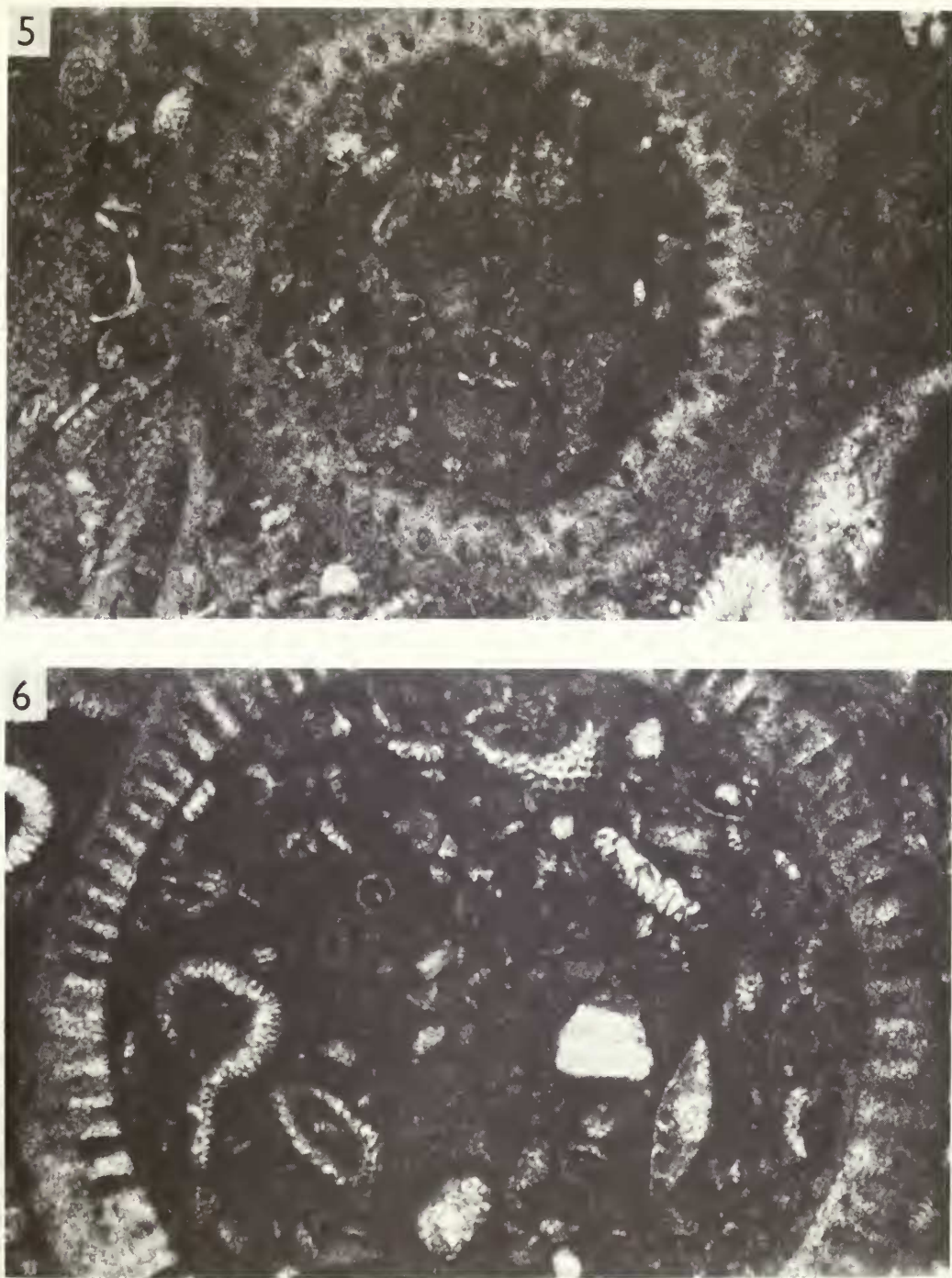
Branches (pores) are numerous and close-set, subcylindrical in shape, medially swollen,

Table 1 Dimensions of *Nanjinoporella*, Measurements in mm: D — outer diameter, d — inner diameter, p — pore diameter, ip — distance between pores, ia — distance between annulations, tha — thickness of annulation.

Sections	D	d	d/D	p	ip	ia	tha
Longitudinal (Fig. 3)	3.63-4.11	3.20-3.68	0.88-0.90	0.094-0.15	0.034-0.094	0.47-0.78	0.067-0.16
Tangential (Fig. 4)	—	—	—	0.11-0.16 ;	0.027-0.11	0.64-0.82	0.067-0.11
Cross (Fig. 5), near distal end	2.67	2.07	0.78	0.054-0.08	0.067-0.12	—	—
Cross (Fig. 6), below Fig. 5	4.21	3.47	0.82	0.067-0.11	0.054-0.11	—	—



Figs 3-4 *Nanjinorella naoda* sp. nov. Lower Permian, Artinskian, Swine Limestone member, Chihhsia Formation, Dawa, Chihhsia Shan Hill, Nanjing, China. Holotype, PB.68055. Thin sections, $\times 12.4$. Fig. 3, longitudinal section. Fig. 4, tangential section.



Figs 5–6 *Nanjinoporella pagoda* sp. nov. Lower Permian, Artinskian. Swine Limestone member, Chihhsia Formation, Dawa, Chihhsia Shan Hill, Nanjing, China. **Holotype**, PB.68055. Thin sections, $\times 31$. Fig. 5, cross section near the distal end of the thallus. Fig. 6, another cross section below that shown in Fig. 5.

and with circular to elliptical cross sections, the longer axes of which are parallel with that of the thallus. They are 0.067–0.16 mm in diameter and slightly constricted at both ends. They grow at right angles to the axis of the thallus or are slightly inclined upwards, and open at both inner and outer surface of the calcareous wall.

Some differences exist in shape, size and arrangement between branches. Sometimes the branches next to the annulation, above and below, have their own calcareous sheaths with rounded closed terminal ends. Their lengths are the same as those of the annulations, longer than the rest of the branches. They are arranged in whorls, while the rest of the branches are irregularly set, or are locally spiral. The spaces between branches (interpores) are 0.27 to 0.12 mm. In longitudinal and tangential sections it can be seen that there are 4–5 rows of branches between consecutive annulations. Fig. 6 is a cross section just through the surface of an annulation, showing a whorl of branches. From a quarter of this section, 21 branches were counted, giving about 80 branches to a whorl.

Fig. 5 is a cross section near the top of the thallus. There are two rows of rounded pores alternately arranged within the calcareous wall, showing that the branches near the top of the thallus become thinner and incline upwards, a common dasyclad feature.

HOLOTYPE. The specimen (Figs 3–6) is from the Swine Limestone member of the Chihhsia Formation, Artinskian, Lower Permian; Dawa, Chihhsia Shan Hill, Nanjing, China. It is housed in the palaeobotany collection of Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing, China. Field collection no. D 501-H 12-5; registration no. PB.68055.

DISCUSSION. The present plant has a long near-cylindrical club-shaped thallus with rounded distal termination. It is not known, however, whether the top of the skeleton of the plant was open or closed. The suggestion that it was closed is proposed here, by analogy with *Epimastopora malaysiana* Elliott (1968a) which is most similar to the present form (see below).

Epimastopora malaysiana is represented by a nearly complete solid specimen with the distal end of the skeleton worn away. Judged from the fact that the surface of the top of the core (filling) is quite smooth, it is believed that the top of the skeleton was closed. If the top was open, the core would have been in direct contact with the external matrix, the removal of which from the fossil would have left a ragged rather than a smooth surface at the top of the core.

It is not clear whether the differences in the lengths of the branches are an original feature or result from different degrees of calcification.

Nanjinoporella is characterized by its unique annulation structure, not known in other dasyclads. However, to some extent it can be compared with certain members of *Epimastopora* Pia, 1922 (cf. *Paraepimastopora* Roux, 1979), among which *E. malaysiana* is the most similar. In being a very large dasyclad with thin calcareous wall, *E. malaysiana* resembles *Nanjinoporella pagoda* in many respects, such as the general shape of the thallus and pores, the ratio of internal to external diameter, the dimensions of pores and interpores, etc. The most remarkable feature of *E. malaysiana* is the existence of internal annulation which results from the intervals between zones of pores, similar to those of *Nanjinoporella pagoda*, but represented by regularly-spaced horizontal sinuous grooves on the surface of the inner core. These inner annulations separate the pores into fascicules of six or seven rows. There is also a trend towards arrangement of the branches into whorls. Paired rows of branches just above and beneath the annulations form horizontal whorls, while the rest of the branches are aspondyl. This pattern is somewhat similar to *Nanjinoporella pagoda*.

Among other differences between these two forms is the basic one that in *Epimastopora malaysiana* there are no outer annulations separating paired rows of euspondyl branches as in *Nanjinoporella pagoda*, except for horizontal lines which correspond in position to the inner annulations. But it is evident that phylogenetically these two forms are very closely related to each other.

A phylogenetic lineage suggested here is that *Nanjinoporella* might have originated from

typical *Epimastopora* through an intermediate link such as *Epimastopora malaysiana*. This evolutionary advance would be achieved by two or three steps. Firstly, an *Epimastopora* with aspondyl branches would give rise to a form with regularly spaced, paired rows of euspondyl branches with smooth intervals left between them. At the same time or a little later these intervals would extend inside to form inner annulations resulting in a new form like *Epimastopora malaysiana*. Finally, these annulations would extend outside to give rise to the outer annulations seen in *Nanjinoporella*.

Since no descendants of *Nanjinoporella* have been found so far, it is assumed that it might represent a specialized side branch in the phylogenetic tree of *Epimastopora*, and *E. malaysiana* may be regarded as an intermediate link connecting typical *Epimastopora* with *Nanjinoporella*.

At present it is difficult to say if *Nanjinoporella* originated directly from *Epimastopora malaysiana* because they are both found in rocks of the same age and more information is needed about their geological ranges. However, it is reasonable to suggest that at least they came from a common ancestor which might be expected in pre-Permian times.

The difficulty in discussing dasyclad phylogeny is that what we are dealing with today are only the calcified skeletons of plants and these vary greatly in the degree of calcification. Hence it is often not known how much is lost. It is not safe to reconstruct evolutionary paths exclusively from the information available from these skeletons. It is quite possible that most of the soft parts of the plant did not leave skeleton traces (cf. Kozłowski & Kaźmierczak 1968, for *Vermiporella*). It is evident that the foregoing suggestion of the phylogeny of *Nanjinoporella* is very tentative and open to emendation according to possible new data available in the future.

Annulation structures in dasyclads

Annulation structures are common in dasyclads, but they vary both in position and in origin between different taxa. The type of annulation developed in most dasycladales may be related to periodic algal growth followed by calcification, which in some other algae results in segmentation. The original random development of branches over the stem-cell surface (aspondyl condition) is modified by:

1. Grouping of branches into annular zones, as in *Epimastopora malaysiana*.
2. Emphasis of this by solid partitions (inner and outer), as in *Nanjinoporella*.
3. Normal verticillate structure, which may be reinforced by (a) external annular calcifications of different types round verticils of branches, as in *Clypeina*, *Pseudocymopolia* etc., or (b) inner annular calcification connected with periodic swelling (waxing and waning) of the stem-cell, as in *Diploporella phanerospora* etc.

It is worth pointing out that *Nanjinoporella* is the only known dasyclad with both inner and outer annulations resulting from the extension of calcareous intervals between branches, and this unique feature makes it clear-cut and distinguishable from other dasyclads.

Annulation structure is given different importance in the classification of dasyclads by different authors. Some authors claim that this kind of structure does not even have specific value (Bassoulet *et al.* 1977). However, others use it as an important criterion to distinguish between different tribes, e.g. the Bereselleae and Palaeoberesellae (Mamet & Roux 1974), although it is not certain if the latter are true dasyclads. In the present case it is used as a diagnostic criterion at generic level.

The function of the annulation of *Nanjinoporella* is not known; this is related to our ignorance of the significance of calcification to the algae. Calcification may strengthen plants mechanically or shield them from high solar radiation, predators etc., but the fact remains that we don't know why they calcify because uncalcified algae flourish side by side with calcified ones in the same environment. Moreover, all the complexities of dasyclad calcification have not prevented their decline to a very subordinate position in the present-day marine flora, compared with that which they held in the past. *Halimeda* has gained at their expense (Elliott 1968b).

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